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INJURY PATTERN OF THE FLASH-BALL®, A LESS-LETHAL WEAPON USED FOR LAW ENFORCEMENT: REPORT OF TWO CASES AND REVIEW OF THE LITERATURE

Peter Wahl, MD, Nicolas Schreyer, MD, and Bertrand Yersin, MD

Centre for Emergency Medicine, University of Lausanne Medical Centre, Lausanne, Switzerland
Reprint Address: Nicholas Schreyer, MD, Centre for Emergency Medicine, University of Lausanne Medical Centre, CH - 1011 Lausanne-CHUV, Switzerland

□ **Abstract—Less-lethal weapons are used in law enforcement to neutralize combative individuals and to disperse riot crowds. Local police recently used such an impact weapon, the Flash-Ball®, in two different situations. This gun fires large rubber bullets with kinetic energies around 200 J. Although it is designed to avoid skin penetration, impacts at such energies may still create major trauma with associated severe injuries to internal organs. This is a report of 2 patients shot with the Flash-Ball® who required medical attention. One could be discharged quickly, but the other required hospitalization for heart and lung contusion. Both patients required advanced investigations including computed tomography (CT) scan. The medical literature on injuries induced by less-lethal impact weapons is reviewed. Impacts from the Flash-Ball® can cause significant injury to internal organs, even without penetration. Investigations as for other high-energy blunt traumas are called for in these cases. © 2006 Elsevier Inc.**

□ **Keywords—less-lethal weapons; impact weapons; Flash-Ball; injury pattern**

INTRODUCTION

Less-lethal weapons are designed to incapacitate individuals rather than to induce fatal injuries. This property makes them interesting in law enforcement, where the use of force is often mandatory to neutralize combative individuals or to disperse riot crowds, but the risk of injury to the target, the officers and bystanders has to be kept to a minimum (1,2). In many countries, less-lethal weapons are not subject to ownership restrictions as severe as for other weapons, thus also making them attractive for self-defense (3,4).

Some years ago, police forces of the city of Lausanne, Switzerland, were equipped with the Flash-Ball®, a firearm designed to fire various types of ammunition at muzzle kinetic energies close to 200 J. One of the possible types is a rubber ball designed to deliver a blunt impact. The manufacturer describes this gun as a "revolutionary defence weapon," with a "dissuasive look and detonation" that "provokes on impact the equivalent of a technical K.O.," thus making it "an impressive and effective intelligent weapon." This weapon was recently used by the local police force's special operations team to neutralize threatening individuals.

We report 2 patients who required medical attention after being shot with this weapon. Medical data on injuries inflicted by similar less-lethal impact weapons available in the literature is reviewed and basic ballistics are discussed.

CASE 1

A 22-year-old man was brought to the Emergency Department (ED) after a loss of consciousness during political demonstrations that took place on a hot and sunny day. He had no complaints upon arrival. As the clinical examination revealed several small round contusion marks on the abdomen and the thighs (Figure 1), he

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Figure 1. Two views of the contusion marks on Patient 1, inflicted by the buckshot ammunition of the Flash-Ball®. The firing range could not be determined.

admitted having been hit some hours before by rubber bullets fired by anti-riot police forces. No detailed information regarding this event could be obtained from the patient. The clinical examination was otherwise noncontributive. Laboratory studies, including liver enzymes, were normal. As the exact energy delivered at impact was unknown, a computed tomography (CT) scan of the abdomen was performed. The examination revealed no sign of any traumatic intra-abdominal lesion. An electrocardiogram (EKG) and a test for orthostasis were also normal.

Final diagnoses were contusions of the abdominal wall and the thighs, and a vaso-vagal syncope probably induced by prolonged standing in the heat, but with no obvious relation to the impact. The patient rejected any analgesic treatment. Later inquiries with the police unit involved confirmed the use of the Flash-Ball® with buckshot ammunition. As buckshot ammunition for the Flash-Ball® contains 9 balls, the fact that the patient showed 10 contusion marks indicates that he was shot at least twice. The exact range at which the patient was shot could not be determined.

CASE 2

A case of domestic violence was investigated by a night patrol of the police. The officers encountered a threatening young man armed with a 30-cm long knife, who showed evident signs of psychological disturbance. He barricaded himself in his apartment. This prompted the officers to call in the Special Operations team. Negotiations were fruitless and the man started to mutilate himself. He was finally neutralized with the Flash-Ball® gun and immediately transported to the ED for medical evaluation. He had been shot once in the lower anterior chest from a distance of approximately 2 m.

Upon admission, this 25-year-old man complained of severe pain in the lower thorax. He presented with impaired and superficial respiration, an oxygen saturation of 91%, and a large contusion mark on the lower anterior chest (Figure 2) with tenderness over the sternum and the epigastrium, and crepitation on palpation of the xyphoid. He also had a dozen superficial transverse cuts on the left forearm and a small wound on the scalp. The rest of the clinical status was normal, in particular pulmonary auscultation and circulatory parameters. Blood gas analysis showed a persistent hypoxemia with an oxygen partial pressure reduced to 58 mm Hg despite adequate analgesia, but no hypocarbia and no alkalosis. No pathologic finding could be identified on a chest X-ray study. A CT scan of the head, the chest and the abdomen revealed a pulmonary contusion. Initial blood sample showed a troponin I level slightly elevated to 0.09 ug/L (N: $<$ 0.04 ug/L), but the EKG was normal. The patient was admitted for observation with the diagnosis of cardiac and

Figure 2. Picture of the chest of Patient 2, showing the large contusion mark close to the lower sternum. The dentate appearance of the borders of the contusion mark were interpreted as skin folds created by the deformation of the thorax at impact. Palpation revealed crepitation of the xyphoid and tenderness at the epigastrium. The firing range was approximately 2 m.

pulmonary contusion and a severe contusion of the anterior chest wall.

As the troponin I increased to a maximum of 1.0 ug/L after 6 h, a transthoracic echocardiogram was performed but revealed no pathologic finding. Creatinine-kinase increased after 6 h to a maximum of 1153 IU/l (N: 25–190 IU/L), which was interpreted as originating mainly from skeletal muscle. Repeated psychiatric evaluation ruled out psychotic disorders and concluded that the patient had an impulsive personality needing no further treatment. Further observation was uneventful, heart enzymes and blood gases normalized. The patient was discharged the next day with oral analgesics.

After this incident, the use of the Flash-Ball® by the local police forces was suspended until further evaluation.

DISCUSSION

Less-lethal technology encompasses a wide array of weapons based on delivery of kinetic energy, chemicals or electromagnetic energy, designed to incapacitate individuals without inducing lethal injury (2,5,6). Although suppliers often underscore the non-lethal character of these weapons, the term less-lethal reflects more accurately the recognized potential of serious injury, even when these weapons are used in optimal conditions. The terminology "less-lethal" furthermore carries potential for confusion, as it implies conventional weapons to be "lethal." However, only 20–25% of war casualties caused by ballistic weapons are fatal, and antipersonnel mines have even a lower lethality (6,7).

The advantage of temporarily disabling the target makes these weapons attractive for law enforcement, especially to neutralize dangerous individuals or to control riot crowds while reducing the risk of injury to the target, the officers and bystanders. An increasing number of law enforcement agencies have less-lethal impact weapons in their arsenals (2). The standoff capability of impact firearms is especially attractive to avoid close contact with the targeted person, thus reducing the likelihood of escalation and need to resort to lethal force (1,2). Due to the recognized potential of severe injury inherent to their use, less-lethal weapons are, however, considered the ultimate step—before the use of deadly force—within the police use-of-force continuum (1,2). The use-of-force continuum is a guideline, developed by and adapted to each law enforcement agency that classifies and defines the coercive force considered adequate to counter specific threats that might confront officers. As legally less-lethal weapons are less strictly controlled in many countries, they are also favored for self-defense (3,4). Injuries from these weapons will certainly become more frequent with their increasing use.

The first less-lethal impact weapon to be used were wooden baton rounds used in Hong Kong in civil riots during the 1950s and 1960s (8). The large scale use of the Royal Ulster Constabulary riot gun by British military and police forces during the unrest in Northern Ireland in the 1970s, however, caused more medical concern (9). Other weapons followed later on during the civil unrest in South Africa (10) and Israel (11,12). The lethal potential of these weapons was soon recognized, and a first report of 90 patients, who had been severely injured, was published in 1975 (9). The risk factors identified for severe or fatal injury by less-lethal ammunition are short range, young age of the person hit, and point of impact on the upper body (2,9,12). Uncontrollable dispersion, induced by the poor ballistic properties of less-lethal ammunition, seems to have been a major contributing factor in hitting sensitive body parts. Despite various attempts to improve accuracy with new ammunition and restricting rules of engagement, the incidence of major injuries remains high (2,10–14).

The Flash-Ball® (Verney-Carron, St-Etienne, France) can fire various types of ammunition, large rubber balls (Figure 3A, used in Case 2), rubber buckshot (Figure 3B, used in Case 1), and balls with coloring or irritating chemicals designed to burst on impact. The manufacturer emphasizes the dissuasive look of this weapon (Figure 4). The kinetic energy of both the rubber ball and the buckshot is indicated to be 200 J. Surprisingly, the same value is given by the manufacturer for muzzle energy at both 2.5 m and 7 m, whereas a significant decrease of the

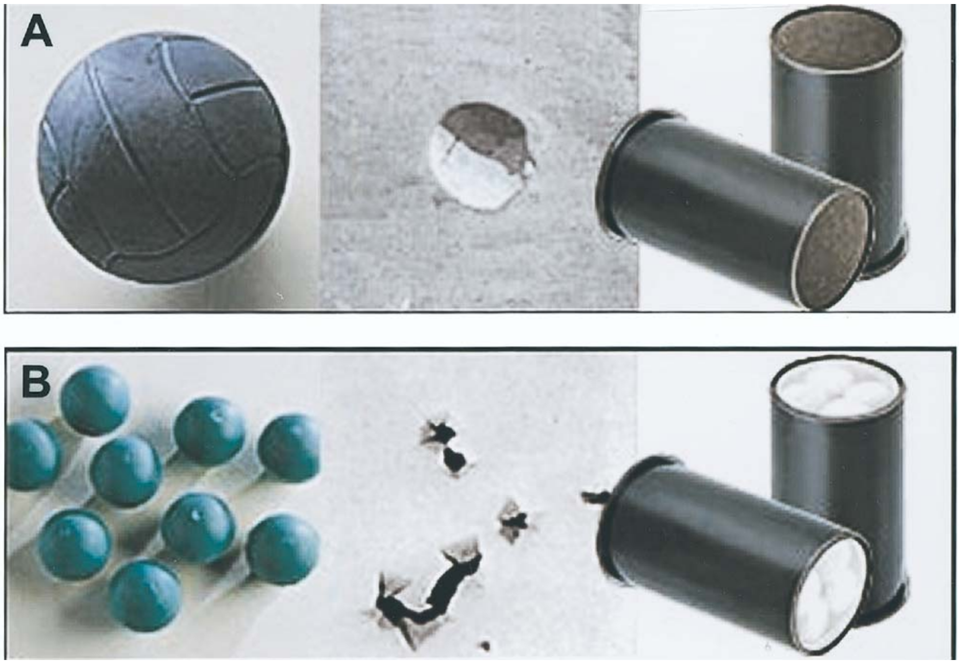

Figure 3. Rubber ball ammunition fired by the Flash-Ball®, with illustrations of the cartridge, the impact and the missile. The indicated impact energy is 200 J for both types. (A) Large rubber ball, caliber 44 mm, weighing 28 g. (B) Rubber buckshot, containing 9 balls of 17 mm. (Illustrations from the manufacturer, Verney-Carron, St-Etienne, France).

kinetic energy due to the important drag of this kind of missile would be expected, at least at 7 m distance (2,15,16). Despite repeated written inquiries and phone calls, no detailed information on the characteristics of both the weapon and the ballistics could be obtained from the manufacturer. Although no data on impact energy are available, the comparison with a major league baseball fastball might be indicative (17). A fastball reaches kinetic energies up to 50 J, but the effect of drag is less marked as it is heavier and slower than the bullets fired from the Flash-Ball®.

Figure 4. View of the Flash-Ball® gun. The manufacturer underscores the dissuasive look of this weapon. (Illustration from the manufacturer, Verney-Carron, St-Etienne, France).

Nevertheless, comparison with other less-lethal impact weapons gives useful insights on the effects of the Flash-Ball®. Although usage of less-lethal impact weapons has increased dramatically in the recent past, systematic information on the physical effects they have on human beings is limited (2). The essential characteristics of the weapons discussed herein have been summarized in Table 1. Muzzle kinetic energy, however, is of only limited usefulness to evaluate the injury potential of weapons firing missiles with a high drag. Except for the Flexible Baton® bean bag where the manufacturer indicates impact energies at a range of 30 feet to be around 100 J, these data are otherwise not available in the weapon specifications and no independent study could be found in the literature.

To our knowledge, the best approximation of the ballistic characteristics of the Flash-Ball® are available in a ballistic study of a similar weapon, the MR 35 Punch® (Manurhin, Mulhouse, France) (18). Measurements revealed the muzzle kinetic energy of the munitions fired from this weapon to be variable, ranging from 150 to 200 J (18). This makes any prediction of the effect at impact uncertain, but according to these results and data supplied by the manufacturers, the MR 35 Punch® is less powerful than the Flash-Ball®. Test firing of the MR 35 Punch® on ordnance gelatine produced deformations of up to 8 cm depth (14). Although deformation of gelatine might be quite different from complex soft tis-

Table 1. Summary of the Essential Characteristics of Some Common Less-Lethal Impact Weapons and Ammunition

Name	Ammunition type	Dimensions	Weight	Muzzle energy
Flash-Ball®	Rubber ball	44 mm	28 g	200 J*
Punch®	Rubber ball	35 mm	21 g	150–200 J
Flexible Baton®	Lead shot + fabric bag	Max 26 cm^2	40 g	160 J*
RUC Riot Gun®	Rubber slug	3.8 × 15 cm	150 g	400 J*
Fiocchi Anticrime Cartridge®	Plastic buckshot	8.5 mm each	15 × 1 g	700 J
Israeli rubber bullets†	Rubber-coated metal buckshot	17–18 mm each	varies	400–775 J*

* Specifications by manufacturer.
† Various models.
RUC = Royal Ulster Constabulary.

sues, this method is widely accepted, and these results clearly indicate a major deformation wherever the human body is struck (16,19).

The so-called "police bean bag" is the less-lethal impact weapon with the most complete description of its injury potential. This munition is composed of a fabric bag containing about 40 g of Nr-9 lead shot pellets and is fired from a 12-gauge shotgun. The bag is designed to deploy to distribute the impact energy on a surface large enough to avoid skin penetration. The most common type in the United States is the TM-12 Flexible Baton® (MK Ballistic Systems, Hollister, CA), which ideally deploys on impact to a maximal cross-sectional surface of 26 cm^2 (2,15,17). Shot penetration after rupture of the bag or incomplete bag deployment (either because it did not separate from the casing or due to firing at short range) has been the cause of many severe or lethal injuries, but this ammunition induced significant injuries even when optimally engaged (2,15,17). Despite an unfavorable evaluation of this ammunition by the U.S. Army in 1974 shortly after its introduction, and recent reports of severe injuries induced by this ammunition, the bean bag has found a wide acceptance, especially among American law enforcement agencies, but also in other countries (2,15,17,20,21).

A North American survey of 373 incidents, where 969 impact munitions were fired, has been published recently (2). Bean bags accounted for two-thirds of the rounds fired, and 37-mm plastic baton rounds for nearly all the rest. Reported rates for injuries more severe than contusions are 5.5% for lacerations, 3.5% for fractures, and 1.8% for penetration. The incidence of fractures was 10% when the shot was fired at a less than 10-foot range. Death attributable to the impact munition occurred in 2.7%. Potential confusion between less-lethal and other shotgun rounds is underscored as breaching slugs, mistakenly fired instead of bean bag munition, led to two additional fatalities. In 7% of the cases, ineffective less-lethal weapons led to use of deadly force. This study admittedly suffers from incomplete data collection, and lesions to internal organs are mentioned without precise figures. The figures reported in this study cannot be transposed to the Flash-Ball® as almost no rubber ball munitions were included. This study, however, gives a good appreciation of the incidence of severe or fatal injuries induced by less-lethal impact weapons.

There is a long list of other types of less-lethal munitions and impact weapons, and many of these have been reported to be more dangerous than expected or suggested by the manufacturers. Among the most dangerous would be the Anticrime Cartridge® (Fiocchi Munizioni, Lecco, Italy), composed of plastic buckshot without any bag encasing fired from a 12-gauge shotgun. This ammunition has a muzzle kinetic energy close to 700 J, superior to many handguns, and consequently has a high penetration rate (3). But less-lethal handguns are also capable of inducing lethal injuries when fired at close range (4).

To fulfill the requirements of reduced lethality, impact weapons must be capable of delivering enough kinetic energy to strike down an individual without inducing life-threatening injury. But both parameters are variable to a high degree (9,11–13). There is ample proof for this statement, because in one of the cases described here (as also described in many other reports), the patients in question had been struck by more than one shot before the police forces could apprehend the target (15,17,20). More than one impact had been necessary in 57% of the incidents analyzed in the above-mentioned police survey before the targeted person could be subdued (2). Five or more impacts had even been necessary in close to 10% of the reported incidents. Stopping power, despite its lack of objectivity, is often used to describe firearms. This is defined as the potential of a missile to strike down an assaulting subject without a possible reaction, or to cause collapse of a fleeing target within 3 m (22). Manufacturer documentation even indicates the stopping power of the Flash-Ball® as being similar to that of a .38 Special, despite major differences in the terminal ballistics of both guns.

Although the wounding potential of a missile is a complex mechanism, it mainly depends on the energy

transferred to the target (16). When tissues are deformed beyond their limits of elasticity or of viscosity, cohesion is lost and the missile might penetrate (12,16). The energy/area ratio necessary for lead bullets to penetrate skin ranges from 19 to 21 J/cm^2 (23). Skin penetration is not to be expected with the Flash-Ball®, as the energy/area ratio of this weapon is 5.7 J/cm^2 considering the flattening of the ball on impact to a surface of 35 cm^2 (specification by manufacturer). Although the energy/area ratio of the various bean bag models is close to 6 J/cm^2 under ideal conditions, penetration with severe or lethal injuries has been described in many cases, either due to faulty ammunition or due to incomplete deployment of the bag when fired at close range (2,15,17,20). The impact produces various strains on the target, including direct compression and propagation of a shock wave, both capable of causing distant injury (12,22). The energy delivered at impact by the bean bag is high enough to produce ruptures of underlying organs even without penetration (2,15,23).

The fact that the weapon is qualified as less-lethal, and the reported absence of skin penetration at impact, might mislead physicians when evaluating patients injured by this kind of weapon (23). Likewise, the exact energy delivered at impact cannot be evaluated with sufficient accuracy to differentiate between low- and high-energy impacts. A physician treating patients hit by such weapons must also be aware that the shock wave generated by the impact of such missiles can induce lacerations, contusions and fractures distant from the point of impact (11,16). We, therefore, recommend that such patients should be investigated rapidly and treated following the same guidelines as other patients who might have suffered high energy blunt trauma.

CONCLUSION

The energy delivered by less-lethal impact weapons is high enough to cause relevant injuries in a significant number of cases. The absence of skin penetration must not mislead the emergency physician into minimizing the potential damage from this kind of weapon. The impact from such a weapon must be considered as a high-energy blunt trauma and be evaluated accordingly. Although less-lethal weapons offer interesting alternatives to law enforcement agencies to subdue combative individuals or to disperse riot crowds, the potential for severe or fatal injuries induced by their impact must be considered when defining the rules of engagement of these weapons.

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